doi: 10.14355/ijer.2015.04.002

Impact of Heavy Metals on Species Richness, Abundance and Vertical Distribution of Soil Microarthropodsin Waste Dump Sites at Delta Steel Company, Warri, Nigeria

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Abstract

Impact of heavy metals in steel industry wastes on species richness, abundance and vertical distribution of soil micro arthropods (mites, collembolans) was investigated at Delta Steel Company premises, Warri, Nigeria. Sampling was conducted fortnightly with a bucket-type auger at 0-10cm, 10-20cm, and 20-30cm depth. Extraction was by modified Bukard model of the Berlese-Tullgren funnel. Results indicated that 21, 8 and15 taxa of microarthropods were recorded at the control, current- dump, and abandoned- dump sites respectively. Five taxa were present in the control but absent from the current- dump and abandoned- dump sites. Seven taxa recorded in the control and abandoned- dump were absent from the current -dump sites. Total abundance was 110 mites (76Cryptostigmata, 32 Mesostigmata, and two Prostigmata) and 12 Collembolans. Distributions among sites were: 65micro arthropods (control), 21 (current-dump), and36 (abandoned - dump). The concentrations of heavy metals were 147.30, 2.50, and 0.12mg/kg for iron, copper and lead, respectively (current- dump), 19.37, 0.09 and 0.02mg/kg for iron, copper, and lead, respectively (abandoned-dump) sites. At the control site, the concentration of iron was 1.65mg/kg; copper and lead were not measurable. A total of 49, 13, and 2 micro arthropods were recorded from depth of 0-10cm, 10-20cm, and 20-30cm, respectively in the control site. At the same respective depth, 6, 11and 5 micro arthropods and 19,11, and 6 micro arthropods were collected from current dump and abandoned dump sites respectively. The variations in abundance among the three sites were statistically insignificant ($F=3.1$; df 8; $p>0.05$). Variations in abundance occurred among depths but the correlation coefficient among them was insignificant($r=0.002$). Average pH was 7.02, 4.95, and 5.14 at the control, current – dump, and abandoned-dump sites, respectively. Metal pollution from steel industry wastes produced an acidic soil and a decline in abundance at the top 10cm of soil.

Keywords

Heavy Metal; Waste Dump Sites; Microarthropods; Species Richness; Abundance; Nigeria

Introduction

Soil microarthropods are minute organisms whose sizes range from slightly more than 0.002 to 1.0cm and including mesofauna (mites and collembolans). They occur in the litter, litter soil interphase and mostly in the top soil to a depth of 10.0cm where organic matter is decomposed and the final products are available to crops. Mesofauna which occurs mostly in the humus is the dominant arthropod taxa in the soil [1].

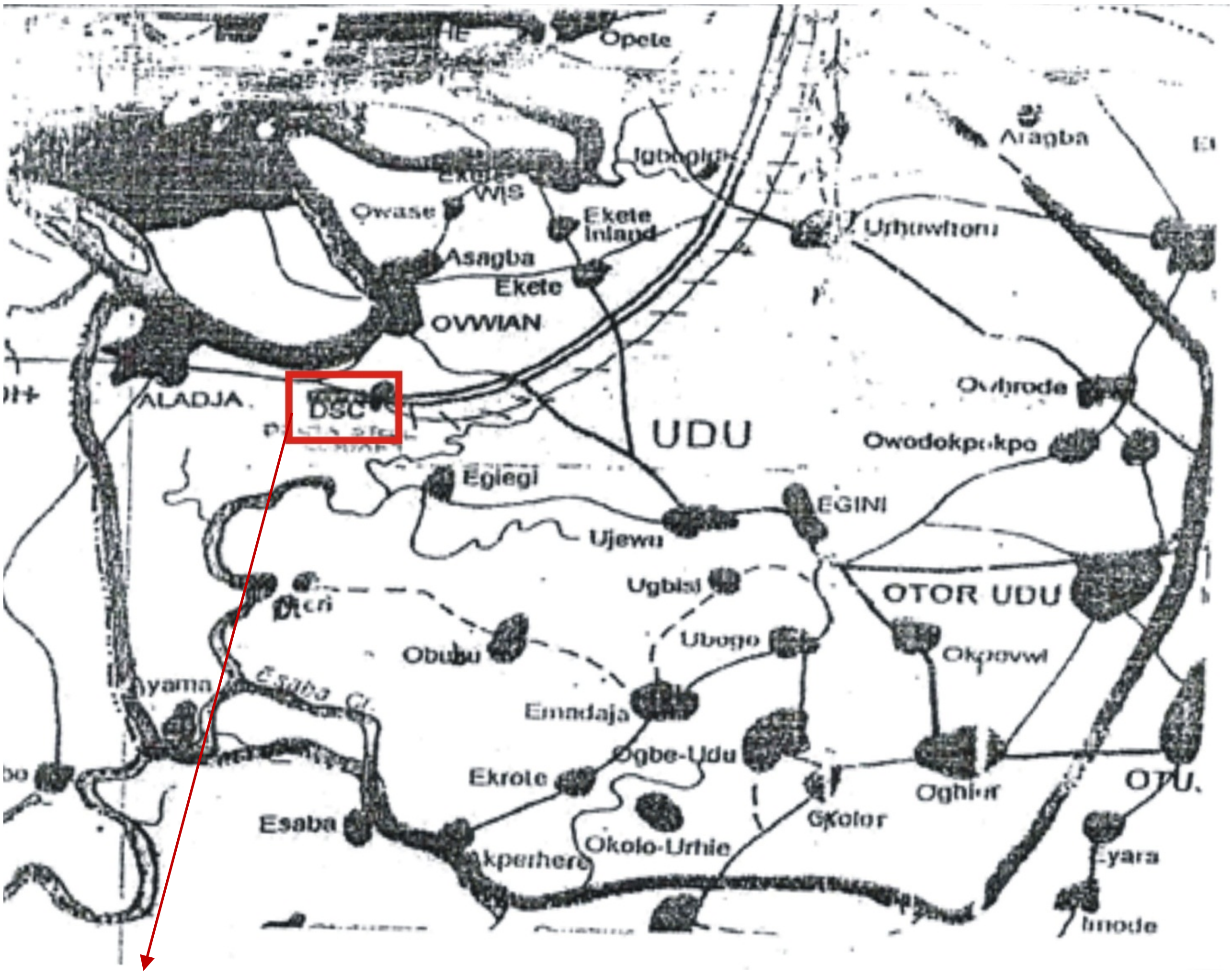
Steel industry is a major source of heavy metal contamination of soils. Steel industry waste introduces metals such as Iron, Lead, Zinc, Copper and Mercury into the soil [2]. These metal deposits remain predominantly in the top few centimeters where soil micro arthropods live and are directly ingested with soil by grazing animals, thereby inhibiting the soil micro-organismic activity [2]. The response of soil micro arthropods to heavy metals has been investigated. They cause a decrease in species abundance [3], and decrease in species richness [4]. Heavy metals such as lead and other metal ions in low concentrations had the greatest negative effect on Oribatids [4].The impact of oil pollution on species richness and abundance of soil micro arthropods in the study area has been reported [5]. Information on the effect of heavy metals on species richness and abundance of soil micro arthropods in the Tropical rainforest of the lower Niger Delta is scanty. This study was conducted to assess the influence of waste from the Delta Steel Company, Warri, Nigeria on the species richness, abundance and vertical distribution of soil

micro arthropods.

Materials and Methods

Study Area

The study was conducted at the premises of Delta Steel Company, Warri, Udu Local Government Area of Delta State, Nigeria (05^{o} 30^{1}.41N and 05^{o} 45^{1}.52E), at three sites: control, current- dumpand abandoned-dump (Fig .1). Each site measured 25x25m. The abandoned – dump site was last used eight years ago while the current-dump site had been used for three years before the commencement of the study.



Delta Steel Company (DSC), Warri

Figure 1. Study Area.

Methods

Soil samples were taken fortnightly from each site with an 8.5cm diameter bucket-type auger over a 3-month period (July- September, 2011). Samples were taken from depth of 0-10cm, 10-20cm, and 20-30cm. The auger was pushed into the first depth range, then into the second and finally into the third. To ensure that all the soil in each depth range was collected, the auger was rotated clock-wise and anti-clock-wise, until the entire soil was taken. Each sample was placed in a plastic bag, labeled and taken to the laboratory for analyses in a 3-stage process (extraction, sorting and identification). Extraction was carried out in a modified Bukard model of the Berlese-Tullgren funnel [6]. Descriptions of the extractor unit and procedure had been documented [7]. Extraction was over seven days and the extracts were sorted by placing them in petri-dishes under a dissecting microscope where mites and collembolans were carefully removed. Temporary slides were prepared and identification was undertaken under a WETZLAR compound microscope, at the Entomology Research Laboratory, University of Port Harcourt.

Identification Keys [8, 9, 10, 11, 12] were used. Identified mites and collembolans were counted and recorded.

Physic-chemical Analyses

One gram of dried soil samples collected from each site was passed through metal digestion process and analyzed by the1985 ASTMD 3921 Atomic Absorption Spectrophotometer (AAS) to obtain the concentrations of the metallic elements present at the respective sites at the Plant Science and Biotechnology Research Laboratory, University of Port Harcourt.

Soil pH was obtained by using 20g of air- dried soil collected from each site and placed in a 50ml-beaker and 20ml distilled water added. The contents were allowed to stand for 30mins. The mixture was stirred occasionally with a glass rod; the electrodes of a pH meter were inserted into the solution from each site to obtain the soil pH.

Moisture content was determined by the use of50g-soil sample from each of the sites. The soil samples were weighed with an electrical balance, wrapped in foil, labeled and placed in the oven for 24hrs. The final weight was taken and the soil moisture content calculated as the percentage of the ratio of the loss weight and the initial weight (Iloba and Ekrakene, 2008) i.e. Moisture Content (%) = Final wt. (wet) – Initial wt. (dry) x 100

Initial (wet)

In each site amercury-in-glass thermometer was inserted and covered with soil to a depth of 10cm. Temperature reading was taken in degree Celsius after 5 minutes.

Results

Species Richness

TABLE 1 SPECIES RICHNESS OF SOIL MICROARTHROPODSIN WASTEDUMPS SITES ATDELTA STEELCOMPANY, WARRI, NIGERIA.

Species	**Dump sites**		
	Control	**Current**	**Abandoned**
CRYPTOSTIGMATA			
*Annecticarus*sp	+	-	+
*Lohmannid*sp	+	+	+
Bicrythermannianigeriana	+	+	+
Atropacarussp	+	-	+
*Schloribates*sp	+	-	+
Mulierculiainexpectata	+	-	+
Archegozttesmagnus	+	-	+
*Belba*sp	+	+	+
*Galumna*sp	+	+	+
*Mixacarus*sp	+	+	+
*Parallonothrus*sp	+	-	-
Nothrusifensis	+	-	-
*Epilomannia*sp	+	-	-
MESOSTIGMATA			
*Rhodacarus*sp	+	+	+
*Parasitid*sp	+	-	+
*Polyaspid*sp	+	+	-
*Trachyuropodide*sp	+	-	-
*Uropodide*sp	+	-	+
PROSTIGMATA			
Bdellidewillisi	+	-	+
COLLEMBOLA			
*Paronella*sp	+	+	+
*Cryptophagus*sp	+	-	-
Total	21	8	15

In the control site, 21 taxa of soil microarthropods were recorded; thirteen of these were Cryptostigmata, five Mesostigmata, one Prostigmata and two collembolans. The species richness at the current- and abandoned-dump sites was 8 and15taxa, respectively (Table 1). Three species of Cryptostigmata (*Nothrusifensis*, *Parallonothrus* and

*Epilomannia*spp), one species each of Mesostigmata (*Trachyuropodide*sp) and a Collembolan (*Cryptophagussp*) which occurred in the controlsite were absent in the current- and abandoned- dump sites (Table 1). Seventaxa, *Mulierculiainexpectata*, *Atropacarus*sp, *Annecticarus*sp, *Archegozettesmagnus* and *Scheloribates*sp (Crypto stigmata), *Uropodide*sp, and Parasitid sp. (Mesostigmata), were recorded in the abandoned- dump site, but were absent from the current- dump site. Eight taxa that occurred in the current-dump site were *Galumna*sp, *Mixacarus*sp, *Bicrythermannianigeriana, Lohmannid*sp and *Belbasp* (Crypto stigmata), *Rhodacarus*sp *and Polyaspidsp* (Mesostigmata), and *Paronella* sp. (Collembola) (Table 1).

Species Abundance

A total of 122 soil micro arthropods, comprising of 110mites and 12 collembolans, were recorded during the study. Among the mites, 76 were Cryptostigmata, 32 were Mesostigmata and 2 were Prostigmata. In the control site, a total of 65 soil micro arthropods were recorded comprising of 36 Cryptostigmata, 20 Mesostigmata, 1 Prostigmata and 8 Collembola (Table 2). A total of 21 soil micro arthropods were recorded in current- dump site while 36 in the abandoned- dump site. Cryptostigmata were dominant among mites in both the control, current-, and abandoned- dump sites (Table 2). Abundance of soil microarthropods decreased with increase in depths. The deeper the depths the decrease in abundance. A total of 74, 35 and 13 soil micro arthropods were collected from 0-10 cm, 10-20cm, and 20-30cm depth ranges, respectively, in all the sites.

TABLE 2 ABUNDANCE OF SOIL MICROARTHROPODS IN WASTE DUMP SITES AT DELTA STEEL COMPANY WARRI, NIGERIA.

	Dump sites			
Microarthropods Groups	**Control**	**Current**	**Abandoned**	**Total**
Cryptostigmata	36	16	24	76
Mesostigmata	20	4	8	32
Prostigmata	1	-	1	2
Sub-total	57	20	33	110
Collembola	8	1	3	12
Total	**65**	**21**	**36**	**122**

At depth of 0-10cm, 42 mites and 7 Collembola were collected at the control site, 5 mites and 1Collembola at the current dump site, and 18 mites and 1Collembola at the abandoned site. At depths of 10-20cm, 12 mites and 1Collembola, 11 mites and no Collembola, and10 mites and 1Collembola were retrieved at the control, current, and abandoned sites, respectively while at depth of 20-30cm, 2 mites and no Collembola, 5 mites and no Collembola, and5 mites and 1Collembola,were recorded at the control, current, and abandoned sites, respectively (Table 3).There was an increase in mite abundance at depths of 0-20cm depth at the current site and a decrease at the abandoned and control sites. Statistically, the differences in abundance of mites at the three sites were significant($F=0.65$; df 8; $p<0.05$) but that of mites and collembolans were insignificant ($F=3.1$; df 8; $p> 0.05$). Correlation between depths and abundance of microarthropods were insignificant ($r =0.002$).

TABLE 3 RELATIONSHIP OF SOIL DEPTH TO ABUNDANCE OF SOIL MICROARTHROPODS IN WASTE DUMPSSITES AT DELTA STEEL COMPANY, WARRI, NIGERIA.

Depth (cm) Micro arthropods	**Dump sites**		
	Control	**Current**	**Abandoned**
Mites			
0.0-10.0	42	5	18
10.0-20.0	12	11	10
20.0-30.0	2	5	5
Collembola			
0.0-10.0	7	1	1
10.0-20.0	1	0	1
20.0-30.0	0	0	1

Heavy Metals Concentration

The concentrations of heavy metals at the control site were 1.65mg/kg, 0.00kg/mg, 0.00kg/mg for Iron, Copper and Lead, respectively and 147.30mg/kg, 2.5mg/kg, and 0.12mg/kg for Iron, Copper, and Lead, respectively at the current- dump site and 19.37mg/kg, 0.90mg/kg, and 0.02mg/kg for Iron, Copper,and Lead, respectively at the abandoned- dump site(Table 4).

TABLE 4. CONCENTRATIONS OF HEAVY METALS IN THE DUMP SITES AT DELTA STEEL COMPANY, WARRI, NIGERIA

	Heavy Metals		
Dump sites	**Iron(Fe)**	**Copper(Cu)**	**Lead(Pb)**
Control	1.65	-	-
Current	147.30	2.51	0.12
Abandoned	19.37	0.90	0.02

Results in Table 5 showed that the average soil temperatures were 26.8^{0}C, 26.0^{0}C, and 25.5^{0}C at the control, current and abandoned, and sites, respectively. Average pH were7.02, 4.95, and 5.14at the control, current, andabandonedsites, respectively, while average % moisture contents were 3.3, 4.5, and6.9 at the control, current, and abandoned sites, respectively(Table 5).

TABLE 5. AVERAGE SOIL PHYSICAL PARAMETERS IN WASTE DUMP SITE AT DELTA STEEL COMPANY, WARRI, NIGERIA.

Dump Sites	**Physical parameters**		
	Temperature (℃)	pH	Moisture (%)
Control	26.8	7.02	3.3
Current	26.0	4.95	4.5
Abandoned	25.5	5.14	6.9

Discussion

The dominance of Cryptostigmata (Oribatida) in this study at the control site was similar to the observations of [13, 14] that oribatid mites were the most numerically abundant and diverse soil mesofauna. The dominance of oribatids in micro arthropods has been extensively documented [15, 16]. Their high numbers might be associated with the diversity of their feeding habits, in spite of their low fecundity and slow development [6]. In the current - and abandoned- dump sites, two categories of species (indicators and monitors) emerged. Three oribatids *(Nothrusifensis*, *Epilomannia* sp. and *Paranothrus*sp), one Mesostitgmatid (*Trachyuropodide* sp.) and one Collembolan (*Cryptophagus* sp.) were sensitive to metal pollution because they were absent in these sites. On the other hand, eight species which persisted in the current- dump site can be categorized as monitor species. Four of those species, *Galumna*sp, *B.nigeriana, Rhodacarus*sp, and *Polyaspid*sp had been categorized as monitor species in oil polluted sites [5].

The highly sensitive species are indicator species as their absence may be taken to indicate a significant level of contamination [17]. The reduction in abundance from the control to the current- and abandoned- dump sites may be attributed to the high waste deposit (slag) of the steel industry which discharges high concentrations of heavy metals at the dump sites. The lower abundance of mesofauna (mites and collembolans) was more pronounced in the current dump site and could be due to the effect of high concentration of metals, especially iron on soil mesofauna. Petroleumoil pollution has been shown to have direct lethal effect on soil microarthropods, with negative impacts on their reproductive rates or indirectly on their food source [18]. The soil pollution might have posed a risk to soil processes and soil-based trophic networks [19].Sub-lethaliron and zinc concentrations decreased feeding activities and growth in collembolans [20] and negatively affected species richness and density [4]. This was probably the situation in the abandoned-dump site with low metal concentration.

Apparently, some species in this study had the ability to withstand stress caused by the metal pollution and persisted in the polluted sites especially at current dump site. These were monitor species that can withstand stress by tolerating high levels, accumulating or excreting the pollutants [17].

The relationship between soil depth and mite abundance could be described as an inverse relationship in both the control and abandoned- dump sites and positively correlated in the current- dump site. In the abandoned- dump

site, the concentration of heavy metals was not high enough to cause a change in the normal distribution pattern of mites in the soil profile, in contrast to the pattern of relationship in the current- dump site. This pattern of relationship had been reported in studies on the vertical distribution of mites in unpolluted [14] and polluted [5] habitats.

The effects of the heavy metals were more severe at 0.0-10.0cm depth since only five mites were recorded from the current- dump site while 18 and 42 were recorded from the abandoned-dump and control sites, respectively. [21] Classified Cryptostigmata into 3 categories (quite susceptible, less susceptible and tolerant) based on their reaction to heavy metals. These categories might also be applicable in this study as the five mites recorded at the dump site at the 0-10cm range could be regarded as tolerant, the less susceptible ones moved deeper beyond 10cm while the quite susceptible mites disappeared from the site. The increase in mite abundance at depths of 10.0cm – 20.0cm in the current- dump site was an indication of probable avoidance of the effects of heavy metals which caused mite migration into lower depths.

The result indicated that soil mites have a wide moisture-range tolerance, 3.3-6.9%.At the control site, the pH was alkaline while in the current-and abandoned- dump sites, it was acidic. The low acidic pH in the current- and abandoned- dump sites, compared with the control site, might have been caused by the higher levels of heavy metals in the polluted sites. [22] stated that soil micro arthropods are normally distributed in the neutral or alkaline soil than in acidic soil. Temperature records at the three sites were similar, indicating that soil temperature had no significant influence on the abundance and distribution of soil microarthropods.

Conclusions

At the control site, most of the mites and collembolans were found at the top 10.0cm of soil where they played key roles in decomposition and mineralization processes [23]. The study showed that heavy metals contained in waste dump sites at Delta Steel, Warri, Nigeria caused a reduction in species richness and abundance from 21 taxa in unpolluted site to 8 and 15 taxa in current and abandoned dump sites respectively. Out of a total abundance of 122 soil microarthropods recorded, 21 and 36 were in current and abandoned dump sites respectively. There was an increase in mite abundance at 0-20cm depth at the current site and a decrease at that same depth at abandoned and control sites. While some species died from the current dump sites, some tolerated the concentration of the heavy metals and persisted at the site, some migrated into deeper depths as the concentration of heavy metals was enough to cause a change in the normal distribution pattern of mites in the soil profile.

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